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UTILITY PATENT APPLICATION TRANSMITTAL
(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No. : 36903/SAH/C715
Inventor(s) : Stanley E. Swirhun, et al.
Title : CLOSELY-SPACED VCSEL AND PHOTODETECTOR FOR APPLICATIONS REQUIRING THEIR INDEPENDENT OPERATION
Express Mail Label No. : EL521381127US

ADDRESS TO: Assistant Commissioner for Patents
Box Patent Application
Washington, D.C. 20231

Date: January 18, 2000

1. **FEE TRANSMITTAL FORM** (Submit an original, and a duplicate for fee processing).

2. **IF A CONTINUING APPLICATION**

 X This application is a divisional of U.S. patent application No. 08/803,891, filed December 11, 1997, which is a continued prosecution application of U.S. patent application No. 08/803,891, filed February 21, 1997, which is a continuation of U.S. patent application No. 08/593,117, filed February 1, 1996. (A copy of this letter is enclosed for filing in the prior application file.)

 This application claims priority pursuant to 35 U.S.C. §119(e) and 37 CFR §1.78(a)(4), to provisional Application No. .

3. **APPLICATION COMPRISED OF**

Specification

 18 Specification, claims and Abstract (total pages)

Drawings

 8 Sheets of drawing(s) (FIGS. 1 to 8A)

Declaration and Power of Attorney

- Newly executed
- No executed declaration
- X Copy from a prior application (37 CFR 1.63(d))(for continuation and divisional)
- X Copy of January 18, 1999 Substitution of Attorney by Assignee

4. **Microfiche Computer Program** (Appendix)

5. **Nucleotide and/or Amino Acid Sequence Submission** (if applicable, all necessary)

- Computer Readable Copy
- Paper Copy (identical to computer copy)
- Statement verifying identity of above copies

6. **ALSO ENCLOSED ARE**

- X Continued Prosecution Application 08/803,891, and Preliminary Amendment to Continued Prosecution Application 08/803,891, both filed December 11, 1997.
- X Preliminary Amendment, filed January 18, 2000.

The PTO did not receive the following listed item(s) Check \$146.50

UTILITY PATENT APPLICATION TRANSMITTAL
(Only for new nonprovisional applications under 37 CFR 1.53(b))

Docket No.: 33723/SAH/C715

- ☐ A Petition for Extension of Time for the parent application and the required fee are enclosed as separate papers
- ☐ Small Entity Statement(s)
- ☐ Statement filed in parent application, status still proper and desired
- ☐ Copy of Statement filed in provisional application, status still proper and desired
- ☐ An Assignment of the invention with the Recordation Cover Sheet and the recordation fee are enclosed as separate papers
- ☒ This application is owned by Cielo Communications, Inc., Broomfield, CO, pursuant to an Assignment recorded at Reel 9719, Frame 0759.
- ☐ Information Disclosure Statement (IDS)/PTO-1449
- ☐ Copies of IDS Citations
- ☐ Certified copy of Priority Document(s) (*if foreign priority is claimed*)
- ☐ English Translation Document (*if applicable*)
- ☒ Return Receipt Postcard (MPEP 503) (should be specifically itemized).
- ☐ Other


7. CORRESPONDENCE ADDRESS

CHRISTIE, PARKER & HALE, LLP, P.O. BOX 7068, PASADENA, CA 91109-7068

Respectfully submitted,

CHRISTIE, PARKER & HALE, LLP

By



Art Hasan

Reg. No. 41,057

626/795-9900

SAH/rvw

IN THE UNITED STATES PATENT AND TRADEMARK OFFICEREQUEST TO FILE A CONTINUED PROSECUTION APPLICATION (CPA) UNDER 37 CFR 1.53(d)

Date: December 11, 1997
 Client/Matter No.: 152236-0059
 Deposit Account No. 09-0946

This is a request to file a continued prosecution application (CPA)
 under 37 CFR 1.53(d) based on prior pending application:

EXPRESS MAIL LABEL NO.:EM139232887US

Inventor(s): Stanley E. Swirhun
 Jeffrey W. Scott
 Serial No.: 08/803,891
 Filed: 02/21/97
 Art Unit: 1107
 Examiner: Joann Stewart
 For: CLOSELY-SPACED VCSEL AND PHOTODETECTOR FOR APPLICATIONS REQUIRING THEIR
 INDEPENDENT OPERATION

Box FWC
 Hon. Commissioner of Patents and Trademarks
 Washington, D. C. 20231

OFFICE OF THE
 SECRETARY

This is a request to file a

- ☒ continuation
☐ divisional
☐ continuation-in-part (for oath or declaration see III below) attached is an amendment for added subject matter
☐ continuing application to permit consideration of an information disclosure statement under 37 CFR 1.97.

application under the file wrapper continuing prosecution application (CPA) procedure of 37 CFR 1.53(d).

1. PARTICULARS OF PRIOR APPLICATION

- A. Application Serial No.: 08/803,891
 C. Date Filed: 02/21/97
 B. Current Title: CLOSELY-SPACED VCSEL AND PHOTODETECTOR FOR APPLICATIONS
 REQUIRING THEIR INDEPENDENT OPERATION
 C. Name of Current Applicant(s) and Their Current Correspondence Address:
 Stanley E. Swirhun Jeffrey W. Scott
 1471 Cassin Court 3455 Table Mesa Drive
 Boulder, Colorado 80303 Apt. 236L
 Boulder, Colorado 80303

2. **INVENTORSHIP STATEMENT**

- (a) ☒ This CPA application discloses and claims only subject matter disclosed in the prior application the particulars of which are set forth above, and the inventor(s) named in the application filed under this request are
- ☒ the same as those named in the prior application.
- ☐ are different than those named in the prior application and it is requested that the following inventor(s) identified above for the prior application be (added/deleted):
- (b) ☐ This application discloses and claims additional disclosure by amendment and a new declaration or oath is being filed. With respect to the prior application, the particulars of which are set forth above, the inventor(s) named in the application filed through this request are
- ☐ the same as those named in the prior application.
- ☐ different than those named in the prior application and requires the (addition/deletion) of the following inventor(s):
- (c) ☐ The inventorship for all of the claims in the application filed through this request is
- ☐ the same
- ☐ not the same, and an explanation, including the ownership of the various claims at the time the last claimed invention was made, is submitted herewith.

3. **DECLARATION OR OATH**

A. Continued Prosecution Application (CPA)

☒ none required

B. Continuation-in-part

☐ attached

executed by (check all applicable items)

☐ inventor(s)

☐ legal representative of inventor(s). 37 CFR 1.42 or 1.43.

☐ joint inventor or person showing a proprietary interest for inventor who refused to sign or cannot be reached. 37 CFR 1.47;

☐ This is the petition required by 37 CFR 1.47 and the statement required by 37 CFR 1.47 is also attached.

☐ not attached

☐ Application is made by a person authorized under 37 CFR 1.41(c) on behalf of all of the above named applicant(s).

☐ Attached is a showing that the filing is authorized.

4. **PRIORITY FROM PRIOR U.S. APPLICATION - 35 U.S.C. 120**

☒ Please amend the specification by inserting before the first line in the first sentence:

☒ --This is a continued prosecution application of copending application Serial No. 08/803,891 filed 2/21/97 which is --

☐ --This is a continuation of copending International Application Number _____ filed under the PCT on ----
_____ and which designated the U.S.--

5. **FOREIGN PRIORITY - 35 U.S.C. 119**

☐ Priority of application Serial No. 0/ _____ filed on _____ in
_____ is claimed under 35 U.S.C. 119.

☐ The certified copy has been filed on _____ in prior U.S. application Serial No. 0/ _____,
which prior application was filed on _____.

☐ certified copy will follow

6. **POWER OF ATTORNEY**

The power of attorney in the prior application names:

IRELL & MANELLA, 1800 Avenue of the Stars, Suite 900, Los Angeles, CA 90067, Robert Steinberg, Reg. No. 33,144;
Bruce D. Kuyper, Reg. No. 33,937; and Gary N. Frischling, Reg. No. 35,515

a. ☐ The power appears in the original papers in the prior application.

b. ☒ The power does not appear in the original papers, but was filed on April 22, 1996.

c. ☐ A new power has been executed and is attached.

d. ☒ Please recognize as associate attorneys: Norman E. Brunell, Reg. No. 26,533; Soyeon Laub, Reg. No. 39,266;
Sam Lu, Reg. No. 40,707 and Flavio Rose, Reg. No. 40,791

e. ☒ Address all future communications to:

Dee Henderson
IRELL & MANELLA LLP
1800 Avenue of the Stars, Suite 900
Los Angeles, California 90067
(310) 277-1010

7. **ASSIGNMENT**

☒ The prior application is assigned of record to Vixel Corporation

☐ An assignment of the invention to:

is attached hereto.

A separate:

☐ "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or

☐ FORM PTO

is also attached.

8. **INFORMATION DISCLOSURE STATEMENT**

☐ An Information Disclosure Statement is submitted herewith.

9. **SMALL ENTITY STATEMENT**

☐ A Verified Statement claiming Small Entity Status is submitted herewith.

☒ A Verified Statement claiming Small Entity Status as an Independent Inventor was filed on 04/22/96, in conjunction with the prior application Serial No. 08/593,117, the filing date for which is 02/01/96.

10. **PETITION FOR SUSPENSION OF PROSECUTION FOR THE TIME NECESSARY TO FILE AN AMENDMENT**

☐ A Petition to Suspend Prosecution is attached hereto for the time necessary to file an Amendment in the new application filed under this request.

11. **IDENTIFICATION OF CLAIMS FOR FURTHER PROSECUTION**

The fees for filing this application are based upon:

☒ the number of claims pending upon entry of the attached preliminary amendment.

☐ entry of the heretofore unentered amendment filed under 37 CFR 1.116 in the prior application, which is hereby requested.

☐ the claims currently pending in the above-referenced prior application.

12. FEE CALCULATION (37 CFR 1.16)

	Basic Filing Fee	\$ 790.00
Total Effective Claims	<u>38</u> - 20 = <u>18</u> x \$22.00	= <u>396.00</u>
Independent Claims	<u>3</u> - 3 = <u>0</u> x \$82.00	= <u>0</u>
If <u>any proper</u> multiple dependent claim is present, add \$260.00		<u>0</u>
[X] Petition under 37 C.F.R. §1.136 is hereby made and the appropriate fee under 37 C.F.R. § 1.17 is filed herewith to extend the term of the pending prior application to <u>November 11, 1997</u> for which the requisite fee is (1 month \$110); (2 months \$390); (3 months \$930); (4 months \$1470).		<u>110.00</u>
[] A copy of a petition for an extension of time already filed in the prior application is attached; subtract any extension fee already paid.		- <u>0</u>
	Subtotal	= <u>\$1,296.00</u>
If "small entity" status box 9 is X'd, enter half (1/2) of subtotal and <u>subtract</u>		- <u>648.00</u>
	Total filing fee enclosed	= <u>\$648.00</u>

13. FEE PAYMENTS BEING MADE AT THIS TIME

[] No filing fee is submitted.	
[X] The filing fee which is attached.	\$648.00
[] Fee for recording assignment(s) if Status Box 7 is X'd (\$40.00 under 37 C.F.R. 1.21(h)).	\$ _____
[] Petition fee for filing by other than all of the inventors or by a person not the inventor where inventor refused to sign or cannot be reached (\$130.00; 37 CFR 1.47 and 1.17(h)).	\$ <u>0</u>
[] Processing and retention fee (\$130.00; 37 CFR 1.53(d) and 1.21(1)).	\$ <u>0</u>
Total fees enclosed:	\$ _____

14. METHOD OF FEE PAYMENT

[X] Attached is our check in the amount of :	\$648.00
[] Charge Account No. <u>09-0946</u> in the amount of:	\$ _____
for which a duplicate of this request is attached.	

15. INSTRUCTIONS AS TO OVERPAYMENT

☒ Credit Deposit Account No. 09-0946

☐ Refund

16. ABANDONMENT OF PRIOR APPLICATION

Please do not abandon the prior application until any petitions for an extension of time or to revive that application have been granted, or until the new application hereby requested has been granted a filing date, such that the prior application is copending with the new application filed under this request. Subject to the foregoing, please append the words --now abandoned-- to the amendment to the specification set forth in paragraph 4 above.

17. DEPOSIT ACCOUNT AUTHORIZATION

The Commissioner is hereby authorized to charge any fee specifically authorized hereafter, or any missing or insufficient fee(s) filed or asserted to be filed or which should have been filed herewith or with any paper filed hereafter, and which may be required under Rules 16-18 (missing or insufficient fee only) now or hereafter relative to this application and the resulting Official document under Rule 20, or credit any overpayment, to our deposit Account No. 09-0946 for which purpose a duplicate copy of this sheet is attached. This statement does not authorize charge of the issue fee until/unless an issue fee transmittal form is filed.

Respectfully submitted,

12/11/97

Date



Norman E. Brunell
Reg. No. 26,533

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

This paper or fee is being deposited with the United States Postal Services "Express Mail Post Office to Addressee" under 37 CFR §1.10 Mailing Label No. EL521381127US

Applicant : Stanley E. Swirhun, et al.
App. No. : Not yet assigned
Filed : January 18, 2000
Title : CLOSELY-SPACED VCSEL AND PHOTODETECTOR
FOR APPLICATIONS REQUIRING THEIR
INDEPENDENT OPERATION

Grp/Div. : Not yet assigned

Docket No. : 36903/SAH/C715

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Post Office Box 7068
Pasadena, CA 91109-7068
January 18, 2000

Commissioner:

Before the first Office Action, please amend the above-referenced application as follows:

IN THE SPECIFICATION:

Before the section entitled "Background of the Invention," please insert the following section:

-- CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application is a divisional patent application of U.S. patent application No. 08/803,891, filed December 11, 1997, which is a continued prosecution application of U.S. patent application No. 08/803,891, filed February 21, 1997, abandoned, which is a continuation of U.S. patent application No. 08/593,117, filed February 1, 1996, abandoned.

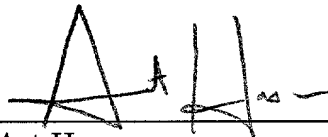
Docket No. 36903/SAH/C715

IN THE CLAIMS:

Please cancel claims 2-21.

Respectfully submitted,

CHRISTIE, PARKER & HALE, LLP

By 
Art Hasan
Reg. No. 41,057
626/795-9900

SAH/rvw

::ODMA\MHODMA\CPHPAS;228686;1

Figure 1 is a schematic representation of the experimental design. It shows a sequence of steps: 1. Selection of 1000 subjects, 2. Random assignment to 500 pairs, 3. Presentation of stimuli (1000 pairs), 4. Collection of responses (1000 pairs), 5. Analysis of responses (1000 pairs), 6. Selection of 1000 subjects, 7. Random assignment to 500 pairs, 8. Presentation of stimuli (1000 pairs), 9. Collection of responses (1000 pairs), 10. Analysis of responses (1000 pairs).

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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Express Mail Label No.EM139232887US

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Date of Deposit

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I hereby certify that this paper (along with any paper referred to as being attached or enclosed) is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date shown below and is addressed to the Assistant Commissioner of Patents, Washington, D.C. 20231.

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PRELIMINARY AMENDMENT UNDER 37 CFR §1.115(a)

Assistant Commissioner of Patents
Washington, D.C. 20231

Sir:

Please enter the following amendments under 37 CFR §1.115(a) in the above referenced application as follows:

In The Claims:

Please cancel claim 1, and add claims 2-39 all as shown below in the full set of all pending claims presented below for the Examiner's convenience.

- 1 2. (Newly Presented) A method of manufacturing monolithic VCSEL
2 and photodetector pairs, said method comprising the steps of:

pbck

3 forming VCSEL layers directly on a semiconductor wafer
4 substrate; then
5 forming photodiodes distributed across said wafer; and
6 dividing said wafer into chips including a VCSEL and
7 photodiode pair.

1 3. (Newly Presented) The method of claim 2 wherein the step of
2 forming VCSEL layers on a semiconductor wafer substrate further
3 comprises:

4 forming first mirror layers;
5 forming a first cladding layer on said first mirror layers;
6 forming an active region on said first cladding layer;
7 forming a second cladding layer on said active region; and
8 forming second mirror layers on said second cladding layer.

1 4. (Newly Presented) The method of claim 3 further comprising
2 the step of:

3 defining active and inactive VCSELs by forming isolation
4 regions therebetween.

1 5. (Newly Presented) The method of claim (3) further comprising
2 the step of:

3 defining active and inactive VCSELs by forming isolation
4 regions around said second mirror layers of said active VCSELs.

1 6. (Newly Presented) The method of claim (3) further comprising
2 the step of:

3 defining active and inactive VCSELs by forming proton
4 implant isolation regions around said second mirror layers of
5 said active VCSELs.

1 7. (Newly Presented) The method of claim (3) further comprising
2 the step of:

3 defining active and inactive VCSELs by forming proton

6 layers to said second cladding layer.

1 (Newly Presented) The method of claim 3 further comprising
2 the step of:

3 forming VCSEL anode contacts on a topmost second mirror
4 layer of said active VCSELs.

1 9. (Newly Presented) The method of claim 3 further comprising
2 the step of:

3 forming VCSEL anode contacts overlapping a topmost second
4 mirror layer and said isolation region of said active VCSELs.

1 10. (Newly Presented) The method of claim 2 wherein the step of
2 forming VCSEL layers directly on a semiconductor wafer substrate
3 further comprises:

4 first forming a plurality of VCSEL cathode layers directly
5 on said semiconductor wafer substrate.

1 11. (Newly Presented) The method of claim 2 wherein the step of
2 forming photodiodes distributed across said wafer further
3 comprises:

4 forming photodiodes directly on said semiconductor wafer
5 substrate at discrete locations.

1 12. (Newly Presented) The method of claim 11 wherein the step of
2 forming photodiodes directly on said semiconductor wafer
3 substrate at discrete locations further comprises:

4 first removing said VCSEL layers on said semiconductor wafer
5 substrate at discrete locations.

1 13. (Newly Presented) The method of claim 2 wherein the step of
2 forming photodiodes directly on said semiconductor wafer
3 substrate further comprises:

4 forming metal-semiconductor-metal photodiodes directly on

5 said semiconductor wafer substrate at discrete locations.

1 14. (Newly Presented) The method of claim 2 further comprising
2 the step of:
3 forming an antireflective coating on said photodiodes.

1 15. (Newly Presented) The method of claim 2 wherein the step of
2 forming photodiodes distributed across said wafer further
3 comprises:
4 forming photodiodes laterally adjacent said active VCSELs

1 16. (Newly Presented) The method of claim 4 wherein the step of
2 forming photodiodes distributed across said wafer further
3 comprises:
4 forming photodiodes distributed on said second mirror layers
5 of inactive VCSELs.

1 17. (Newly Presented) The method of claim 3 wherein the step of
2 forming photodiodes distributed across said wafer further
3 comprises:
4 forming distributed p-type layers on a topmost second mirror
5 layer;
6 forming an intrinsic layer on said distributed p-type
7 layers;
8 forming an n-type layer on said intrinsic layers;
9 forming a photodiode cathode contact on each of said n-type
10 layers; and
11 forming distributed photodiode anode contacts on said
12 topmost second mirror layer.

1 18. (Newly Presented) The method of claim 5 further comprising
2 the step of:
3 prohibiting operation of said inactive VCSELs by
4 electrically short circuiting said semiconductor wafer substrate

5 to said photodiode anode contact.

1 19. (Newly Presented) A method of manufacturing an integrated
2 VCSEL and photodetector pair, said method comprising the steps
3 of:

4 forming layers of a VCSEL on a semiconductor substrate;

5 forming layers of a photodiode on a top-most layer of a
6 first portion of said VCSEL layers;

7 isolating a second portion of said VCSEL layers from said
8 photodiode layers by implanting an isolation region between said
9 first and second portions of said VCSEL layers;

10 forming a VCSEL cathode contact connected to said
11 semiconductor substrate;

12 forming a VCSEL anode contact connected to said top-most
13 VCSEL layer in said second portion;

14 forming a photodiode cathode contact on a topmost layer of
15 said photodiode layers; and

16 forming a photodiode anode contact on said top-most VCSEL
17 layer of said first portion of said VCSEL layers.

1 20. (Newly Presented) The method of claim 19 wherein the step of
2 forming a VCSEL anode contact connected to said top-most VCSEL
3 layer in said second portion further comprises:

4 forming a VCSEL anode contact overlapping said top-most
5 VCSEL layer in said second portion and said isolation region.

1 21. (Newly Presented) The method of claim 19 further comprising
2 the step of:

3 prohibiting operation of said first portion of said VCSEL
4 layers as a VCSEL by electrically short circuiting said substrate
5 to said topmost layer of said VCSEL layers in said first portion.

1 22. (Newly Presented) A monolithic optical transmitter and
2 receiver pair comprising:

3 a semiconductor substrate;
4 an optical transmitter formed on said substrate; and
5 an optical receiver formed laterally adjacent said optical
6 transmitter, said optical receiver optically and electrically
7 isolated from said optical transmitter.

1 23. (Newly Presented) The device of claim 22 wherein said
2 optical receiver further comprises:
3 a photodiode.

1 24. (Newly Presented) The device of claim 22 wherein said
2 optical transmitter further comprises:
3 a VCSEL having a plurality of layers.

1 25. (Newly Presented) The device of claim 24 wherein said VCSEL
2 further comprises:
3 an isolation region defining discrete areas of active VCSEL
4 layers and discrete areas of inactive VCSEL layers.

1 26. (Newly Presented) The device of claim 25 further comprising:
2 means for disabling inactive VCSEL layers.

1 27. (Newly Presented) The device of claim 22 wherein said
2 optical transmitter further comprises:
3 first mirror layers formed on said substrate;
4 a first cladding layer formed on a topmost first mirror
5 layer;
6 an active region formed on said first cladding layer;
7 a second cladding layer formed on said active region; and
8 second mirror layers formed on said second cladding layer.

1 28. (Newly Presented) The device of claim 27 wherein said active
2 region further comprises:
3 at least one quantum well layer.

1 29. (Newly Presented) The device of claim 28 wherein said first
2 and second mirror layers further comprise:
3 epitaxially grown distributed Bragg reflectors.

1 30. (Newly Presented) The device of claim 22 wherein said
2 optical receiver further comprises:
3 a photodiode formed on a topmost second mirror layer of said
4 inactive VCSEL layers.

1 31. (Newly Presented) The device of claim 22 wherein said
2 optical receiver further comprises:
3 a p-type layer formed on a topmost second mirror layer of
4 said inactive VCSEL area;
5 an intrinsic layer formed on said p-type layer;
6 an n-type layer formed on said intrinsic layer;
7 a photodiode cathode contact formed on said n-type layer;
8 and
9 a photodiode anode formed on said topmost second mirror
10 layer.

1 32. (Newly Presented) The device of claim 26 wherein said means
2 for further comprises:
3 an electrical short circuit between said substrate and said
4 photodiode anode.

1 33. (Newly Presented) The device of claim 22 further comprising:
2 a non-reflective coating on said optical receiver.

1 34. (Newly Presented) The device of claim 22 wherein said
2 optical receiver further comprises:
3 a photodiode formed on said semiconductor substrate.

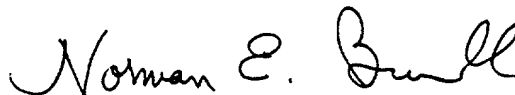
1 35. (Newly Presented) The device of claim 31 wherein said
2 photodiode further comprises:

- 3 a metal-semiconductor-metal photodiode.
- 1 36. (Newly Presented) An array of monolithic optical transmitter
2 and receiver pairs formed by the process of claim 19.
- 1 37. (Newly Presented) An matrix of monolithic VCSEL and
2 photodetector pairs formed by the process of claim 2.
- 1 38. (Newly Presented) A monolithic optical transmitter and
2 receiver pair formed by the process of claim 13.
- 1 39. (Newly Presented) A monolithic optical transmitter and
2 receiver pair formed by the process of claim 18.

REMARKS

The above claims were added to clearly distinguish the present invention. Applicant respectfully requests that the Examiner allow the claims and pass this case to issue.

Respectfully Submitted,
Irell & Manella LLP



Norman E. Brunell, Reg. No. 26,533

1800 Avenue of the Stars, Suite 900
Los Angeles, CA 90067-4276

(310) 277-1010
(310) 203-7199 Facsimile
nbrunell@irell.com

A CLOSELY-SPACED VCSEL AND PHOTODETECTOR
FOR APPLICATIONS REQUIRING THEIR INDEPENDENT OPERATION

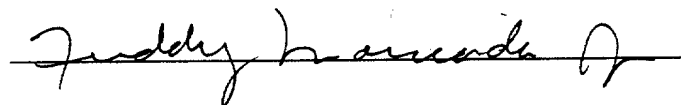
Inventor(s): Stanley E. Swirhun
Jeffrey W. Scott

Authored by: Robert C. Strawbrich
Irell & Manella
1800 Avenue of the Stars
Los Angeles, CA 90067

Certificate of Express Mail

Express Mail Label No. GB 971 047 913 US
Date of Deposit February 1, 1996

I hereby certify that this correspondence/fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" Service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231

 _____ Signature

A CLOSELY-SPACED VCSEL AND PHOTODETECTOR
FOR APPLICATIONS REQUIRING THEIR INDEPENDENT OPERATION

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

5 The present invention relates to vertical cavity surface emitting lasers (VCSELs) and photodetectors, and more particularly to the application of such optoelectronic devices where they must operate independently but where it is also desirable to have a transmitter and a receiver closely-spaced.

2. ART BACKGROUND

10 There are a number of data communications applications which make use of optoelectronic sending and receiving devices (i.e. light emitters and photodetectors). For fiber optic data communication applications requiring less than 200 MBits/sec., light emitting diodes (LEDs) are the light emitters of choice because they are relatively inexpensive to manufacture. For applications requiring higher speeds, lasers are used as
15 the light emitters.

 Until recently, most high speed data communications applications employed edge emitting lasers in a serial (single channel) format. With the advent of Vertical Cavity Surface Emitting Lasers (VCSELs), many such applications are now implemented using VCSEL arrays which can be interfaced to ferrules carrying multiple fibers to transmit
20 several bits of data in parallel. At the receiving end, an array of photodetectors is coupled to the multiple fibers. It is the ability to manufacture VCSELs in arrays (an advantage of LEDs) combined with their high speed of operation (an advantage of lasers) which makes VCSELs desirable in such applications.

 For high-speed serial duplex data communications applications, however,
25 separately packaged light emitters (usually edge emitting lasers) and photodetectors are

still employed. For long-haul applications (typically having distances greater than 1 kilometer), wavelength division multiplexing is often employed to transmit and receive data for a duplex channel over the same fiber. Because the primary cost of a long-haul duplex serial data channel resides in the fiber and its installation, complex beam-splitting techniques can be justified at the ends of the channel to separate the transmit and receive data streams from the single fiber.

For short-haul or "premises" applications, however, the cost of fiber and fiber installation is relatively less important than the cost of the many transmit and receive functions. Thus, it is the cost of the data transmit and receive components, and particularly the optoelectronic devices and their packaging, which drives cost considerations for short-haul applications. Typical short-haul implementations of a high-speed serial fiber optics data communications channel operating in full duplex still employ two multimode fibers; each one to connect an individually packaged transmitting light emitter to an individually packaged receiving photodetector. This is because the cost of complex beam-splitting components can not be justified.

Figures 1a and 1b illustrate the components comprising a typical implementation of a transmit or receive link for a short-haul high-speed duplex data communications application. Figure 1a illustrates a fiber assembly 12. A round ferrule 26 houses an optical fiber 28 which is located precisely in the center of ferrule 26. A typical diameter for ferrule 26 is approximately 2.5mm. Ferrule 26 comes with a latching mechanism 30 which is used to clamp and secure the ferrule to a barrel 32 of an optical sub-assembly 10 which is depicted in Fig. 1b. Barrel 32 houses optoelectronic device 14 typically in a TO can package 16 which is centrally located in the barrel as shown. Optoelectronic device 14 is typically located at an appropriate point within can 16 by a standoff 2. Driver or amplifier circuitry is coupled to optoelectronic device 14 through leads 22. A window 18 is provided in the top of the can package to allow transmitted light out or received light in, depending upon whether the optoelectronic device is a light emitter or a photodetector. The TO package is aligned with fiber 28 and epoxied using epoxy 24 to fix the position of the optoelectronic device with respect to the ferrule 26 and hence

fiber 28. Optical elements such as lens 20 are typically provided to focus the light for optimal optical efficiency, particularly where the light emitter is an edge emitting laser. Barrel 32 is designed to mate with latching mechanism 30 of fiber assembly 12.

Both fiber assembly 12 and barrel 10 are precision manufactured for precise mating. Active alignment TO package 16 and optoelectronic device must be performed in the x, y and z axes. First, the optoelectronic device must be precisely aligned within the package 16. Second, the package 16 must be precisely aligned within barrel 10. Finally, optical element 20 must be precisely aligned with respect to its distance from the optoelectronic device 14 to achieve proper optical operation. Because a separate package is required for both the transmit side and the receive side of the duplex data channel, a total of twelve active alignments must be performed for each channel and each channel includes the cost of eight precision-manufactured coupling parts.

Figures 1c and 1d provide a schematic illustration of the fiber assembly 12 and optoelectronics subassembly 10 of Figures 1a and 1b respectively.

Figure 2 illustrates a typical duplex serial data communications module 40, which has mounted to it an optical subassembly 52 containing a light emitting device 13 disposed in a TO can package 9 having a window 17, which is to be mated with an optical fiber assembly 46 and which is dedicated to data transmission. Module 40 also has an optical subassembly 50 mounted to it containing a photodetector 15 disposed in TO can package 11 and which is to be mated with optical fiber assembly 48 and dedicated to receiving data from a remote module not shown. Because of the differing optical requirements of the transmit and receive devices, the modules must often be mounted in a staggered fashion as shown. Moreover, the transmit devices are located at an optically appropriate point in their can packages by standoffs 4 and 6 respectively.

Because of the cost of the precision components and the large number of alignments required for implementing duplex serial modules 40, it is highly desirable to integrate the transmit and receive optoelectronic devices (i.e. light emitter and

photodetector) into one package. The integration of the two devices into a single package is not, however, an easily achieved solution. The prior art implementations as illustrated in Figures 1a-d and 2 cannot be readily adapted to multifiber ferrules currently available for unidirectional data transmission using VCSEL arrays. These multifiber ferrules have fiber spacings which are typically about 250 microns and can be less. The diameter of the TO can package 14 commonly used in present implementations is itself 5600 microns in diameter. Thus, the standard ferrule and barrel would have to grow substantially in diameter to accommodate two fibers having the spacing dictated by the TO cans housing the optoelectronic devices.

Even if a substantially larger barrel could be created to integrate the light emitter and photodetector as commonly packaged to receive both a transmit and a receive fiber, it is not clear that the resulting package could provide the necessary separation of incoming and scattered outgoing light beams to prevent crosstalk between the transmit and receive signals (at least not without complex optics and possibly some form of isolation). Although solutions have been disclosed to stack a light emitter (typically an LED) on top of a photodetector to transmit and receive wavelength division multiplexed signals (the light emitter is transparent to the received wavelength), beam-splitting must still be employed at the opposite end.

Thus, there is room in the art for an improvement in the area of optoelectronic device fabrication which facilitates the integration of one or more pairs of transmit and receive devices for interface with a single ferrule carrying one or more pairs of fibers having spacings as little as 250 microns or less, to substantially reduce the cost and complexity of implementing high-speed serial duplex data communications channels.

In a first preferred embodiment of the invention, one or more VCSELs are formed using a known process for manufacturing such devices. The one or more VCSELs comprise an n-type GaAs substrate and a first mirror formed on the substrate, which is a well-known distributed Bragg reflector (DBR) a first spacer or cladding layer which is formed on top of mirror. This first mirror is also doped n-type. An active region is then formed on top of the first mirror, the active region comprising at least one quantum well layer or bulk layer. A second spacer or cladding layer is formed on the active region, with a second DBR being formed on the second spacer layer and doped to have p-type conductivity.

On top of the VCSEL layers is grown an etch-stop layer of AlGaAs having about 90% or greater Al content. An extended p-type layer of AlGaAs having more typical alloy proportions is then grown on top of the etch-stop layer. On top of this p-type layer is grown an intrinsic layer (i) which is undoped GaAs. On top of the intrinsic layer is grown an n-type region of AlGaAs. An etching process is then performed to etch away the extended p, i, and n layers where the one or more VCSELs are to be formed. The etching process uses the etch-stop layer to mark the end of the etching process so that the VCSEL area has exposed the top surface of an appropriately designed mirror. A proton implant region is created which separates the one or more VCSELs and the photodetectors formed by the unetched p, i, and n layers. Anode contacts are formed over the non-implanted p regions to form apertures for the VCSELs. A VCSEL cathode contact is formed on the substrate. Anode contacts are also formed on the p region of the p-i-n photodiode and a cathode contact is made to the n region of the p-i-n photodiode.

Thus, in this preferred embodiment, a VCSEL circuit can be isolated from a p-i-n photodiode using a proton implant isolation region which is commonly used to isolate VCSELs formed in arrays. The anode contacts to the p region of the p-i-n photodiode may be coupled to ground so that the VCSEL structure which lies underneath the p-i-n photodiode is never turned on and other bipolar parasitic effects are avoided. The width of the proton implant isolation region is typically between 50 and 100 microns. Thus,

SUMMARY OF THE INVENTION

5 It is therefore an objective of the present invention to provide a VCSEL device sufficiently close to a photodetector device to permit the use of commercially available multifiber ferrules having fibers spaced on the order of 750 microns to 250 microns or less.

It is a further objective of the present invention to provide the closely-spaced but independently operable optoelectronic devices by monolithically integrating the two devices on the same substrate.

10 It is still further an objective of the invention to provide a process by which multiple pairs of VCSELs and photodetectors can be arrayed on the same substrate.

It is still further an objective of the invention to provide a process by which the closely-spaced but independently operable optoelectronic devices can be packaged using known lead-frame or ceramic packaging technologies.

15 It is still further an objective of the invention to integrate any requisite optics with either the semiconductor manufacturing technology or the packaging technology.

It is still further an objective of the present invention to simplify significantly the alignment of the fibers to the closely-spaced optoelectronic devices by taking advantage of the photolithographic nature of monolithic semiconductor processing to precisely define the separation between the optoelectronic devices.

20 It is still further an objective of the invention to provide closely-spaced but independently operable VCSEL and photodetector pairs capable of near-field operation requiring no optics and which permit butt coupling between a package containing the optoelectronic devices and a flat faced multifiber ferrule.

the VCSEL and the p-i-n photodiode can be separated by an accurately known distance, significantly less than 250 microns if desired. Moreover, the difference in thickness between the VCSEL and the p-i-n photodiode is small, thereby permitting near-field coupling of the optoelectronic devices to fibers.

5 One significant advantage of the first embodiment of the invention is that it requires very few additional steps to an otherwise typical VCSEL manufacturing process. A second advantage is that, when an anti-reflection coating of silicon nitride is applied to the photo-receiving n region of the photodiode, in conjunction with the p-type mirror which underlies the p-i-n photodiode, a high degree of efficiency is achieved. The
10 silicon nitride anti-reflection coating increases transmission of incoming light into the surface of the p-i-n photodiode. Additionally, any light which is not absorbed by the intrinsic layer of the photodiode on its way through will be reflected from the underlying p-type mirror back into the intrinsic layer and will then have a second opportunity to be absorbed.

15 A second preferred embodiment of the invention employs a VCSEL with an MSM photodiode. The VCSEL is manufactured on a semi-insulating substrate. Because the MSM photodetector employs the semi-insulating layer as its common cathode, the two optoelectronic devices are virtually isolated from one another electronically as a result. A photolithographically defined minimum spacing of 250 microns or less can
20 also be achieved using the second preferred embodiment of the invention. An anti-reflection coating is also preferably employed over the MSM photodetector to increase efficiency. To further enhance electrical isolation between the two devices, an isolation region can also be formed, preferably by implantation. Another advantage of using an MSM photodiode is that the two anode terminals can be used to drive a differential
25 amplifier, thereby permitting common-mode rejection of noise.

Either of the two preferred embodiments can be integrated with optically transmissive materials which can be formed into lenses on the surface of the semiconductor. Either embodiment can also be implemented within standard precision

manufactured barrels to be aligned with circular ferrules containing multiple fibers. Finally, either embodiment can be encapsulated using known lead-frame or ceramic packaging technology to permit near-field flat coupling between a flat package having an optically transmissive surface and a commercially available flat rectangular ferrule containing multiple fibers.

The foregoing objectives and the features of the preferred embodiments will be understood by those of skilled in the art with reference to the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1a (prior art) illustrates a fiber assembly of a typical implementation of a high-speed data transmission link using a single optoelectronic device for each half of a duplex channel.

5 **Figure 1b** (prior art) illustrates an optical assembly of a typical implementation of a high-speed data transmission link using a single optoelectronic device for each half of a duplex channel.

Figure 1c (prior art) illustrates a schematical view of the fiber assembly of Fig. 1a and the optical assembly of Fig 1b.

10 **Figure 1d** (prior art) illustrates the high-speed duplex data communications module using known precision manufactured parts to implement the transmit and receive links of a high-speed duplex data communications channel of Fig. 2.

15 **Figure 2** (prior art) illustrates a high-speed duplex data communications module using known precision manufactured parts to implement the transmit and receive links of a high-speed duplex data communications channel.

Figure 3 illustrates a cross-section of an integrated VCSEL and an MSM photodetector in accordance with the present invention.

Figure 4 illustrates a monolithic plan view of a preferred embodiment of the invention.

20 **Figure 5a** illustrates a cross-section of a VCSEL and a p-i-n photodiode in accordance with the present invention.

Figure 5b illustrates the orientation of the VCSEL laser diode and the p-i-n photodiode as illustrated by the cross-section in Figure 5a.

Figure 6a (prior art) illustrates a commercially available dual fiber version of a round fiber ferrule.

5 **Figure 6b** (prior art) illustrates a commercially available rectangular multifiber ferrule.

Figure 7a illustrates how the present invention can be packaged using conventional lead-frame technology to facilitate interface to a rectangular multifiber ferrule.

10 **Figure 7b** illustrates how optical lenses can be integrated with the present invention.

Figure 7c illustrates how the present invention can be implemented using butt coupling technology.

15 **Figure 8** illustrates how a transmit and receive pair made in accordance with the present invention can be packaged to interface with a round multifiber ferrule such as the one illustrated in Fig. 6a.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is a monolithic semiconductor device having a VCSEL integrated with a photodetector on the same substrate, the VCSEL and photodetector to be operated independently as a transmit and receive device respectively. The VCSEL and photodetector are physically situated in close enough proximity to permit packaging of one or more pairs of the VCSEL and photodetector such that they may be coupled to multifiber ferrules having fiber spacings on the order of 250 microns or less. The present invention also includes a method of manufacturing the independently operated VCSEL and photodetector, as well as the packaging and coupling of one or more pairs of the integrated VCSEL and photodetector and their coupling to multifiber ferrules.

A first preferred embodiment of the invention is now discussed in detail in conjunction with Figures 3 and 4. As shown in Figure 3, a VCSEL and a metal-semiconductor-metal (MSM) photodetector are integrated on the same semi-insulating GaAs substrate. The conductance of the semi-insulating substrate is typically between about 10^{-12} and 10^{-5} ohm-cm. The VCSEL is built on top of the substrate beginning with an n- layer 68, upon which an n+ layer 70 is grown which forms the cathode of the VCSEL.

A first mirror is formed on layer 70, which is preferably an epitaxially formed distributed Bragg reflector (DBR) which comprises a plurality of alternating semiconductor layers having high and low indices of refraction, with each layer having a thickness of $\lambda/4n$, where λ is the wavelength of the optical radiation emitted from the laser and n is the index of refraction of the layer. The semiconductor layers are doped to achieve n-type conductivity. A quantum well (QW) active region 74 is formed between a first spacer 73 and a second spacer 75, with first spacer 73 formed on the top layer of the first mirror. Active region 74 has at least one QW layer.

A second mirror 76 is formed on second spacer 75 and is preferably an epitaxially grown DBR which is comprised of a plurality of alternating semiconductor

layers having high and low indices of refraction, with each layer having a thickness of $\lambda/4n$, where λ is the wavelength of the optical radiation emitted from the laser and n is the index of refraction of the layer. The second mirror 76 is doped to achieve a p-type conductivity. An isolation implant 80 is formed around the second mirror 76, and preferably extends to a depth just inside spacer 75. A mesa region is then etched around the outside of the VCSEL 89 to a depth which exposes the cathode layer 70. A cathode contact 72 is then formed on the exposed surface of cathode layer 70, and an anode contact is formed which overlaps the surface of isolation implant region 80 and the top-most layer of second mirror 76, and which further defines an aperture 88 which comprises a portion of the surface of the top-most layer of second mirror 76. Radiation 84 is emitted through aperture 88.

The MSM photodetector 62 is formed on the surface of the semi-insulating substrate 60 as two non-electrically coupled metal patterns 62 and 64, each having fingers which are interdigitated with one another. When one or both of the patterns is biased to some voltage, carriers generated by received light are swept to the anodes of the two diodes by the applied electric field. Because the MSM operates without conducting any current through the substrate 60, there is virtually no electrical crosstalk or leakage between the VCSEL 89 and the MSM photodetector 62. Thus, the VCSEL 89 can emit radiation 84 from aperture 88 based on digital data to be transmitted while MSM photodetector 62 can receive radiation 86 in which is encoded digital data received from a remote data source. To achieve even better isolation, an isolation region 80 can be formed preferably by proton implant between VCSEL 89 and MSM photodetector 62.

Figure 4 illustrates a plan view of the device which is shown as a cross-section in Figure 3. For clarity, corresponding structures will be indicated by identical index numbers. The cathode 70 and its metal contact 72 of the VCSEL are extended to the boundary of substrate 60 which is furthest away from MSM photodetector 86. Bond wire 71 can then be used to connect cathode contact 72 to a bond pad of, for example, a lead frame. The VCSEL anode contact 82 is brought to the same substrate boundary by bond wire 77, metal extender 79 and bond wire 69. Metal patterns 66 and 64, which

form the anode and anode terminals of MSM photodetector 62, are also bonded to the leads of whatever form of packaging is used. One of the metal patterns is typically coupled to a bias voltage while the other is coupled to ground or a different bias voltage. An anti-reflection coating can be employed on the MSM to increase optical efficiency.

5 A second preferred embodiment is disclosed in Figure 5a. For convenience and clarity, like structures will be denoted by the same index numbers as in previous figures. This particular embodiment is preferred because it can be implemented using more standard VCSEL manufacturing processes. A first mirror 78 is formed on a standard semiconductor GaAs substrate 79. The first mirror is preferably a semiconductor DBR
10 comprising twenty to thirty periods of AlAs/AlGaAs layers. Each of the layers has a thickness of $\lambda/(4n)$ and is doped to have n-type conductivity. A first spacer or cladding layer 73 is then formed on first mirror 78, which is either undoped or very lightly doped. An active region 74 is then formed on the first spacer 73 which comprises at least one GaAs QW layer. A second mirror 76 is then formed on top of a second
15 undoped or very lightly doped spacer or cladding layer 75. The second mirror 76 again preferably consists of alternating layers of AlAs/AlGaAs layers, each being $\lambda/(4n)$ thick. Second mirror 76 is doped to have p-type conductivity. On top of second mirror 76 is formed a thin etch-stop layer 93, which has a significantly higher ratio of Al to Ga, about 9 to 1 or greater. On top of the etch-stop layer 93, an extended p-type layer 100 of AlGaAs is formed. On top of p-type layer 100 is formed an intrinsic layer (i) 102 of undoped GaAs. Finally, an n-type layer 104 is formed on top of intrinsic layer 102.
20

The structure is then etched in those areas where a VCSEL is to be formed, and not etched where a p-i-n photodiode is to be formed. The etch strips away the n-type layer 104 and intrinsic layer 102 and continues into p-type layer 100 until the etch-stop
25 layer 93 is detected. The etching process is terminated so that the etch-stop layer is etched away and an appropriately thick top layer of second mirror 76 is exposed. Those of skill in the art will recognize that there are other well-known techniques by which the endpoint of an etching process may be detected to end the etching process at the appropriate time and which are intended to be within the scope of the present invention.

A proton isolation implant is performed to create isolation region 80 between VCSEL 92 and p-i-n photodiode 90. The implant region 80 typically achieves a depth which extends just inside spacer layer 75 and has a width preferably between about 50 and 100 microns. A circular metal contact 82 is then formed on the top of mirror 76 and which overlaps slightly implant region 80. Contact 82 provides access to the anode of VCSEL 92. A contact 81 is then formed on the back side of substrate 79 and serves as the cathode terminal of VCSEL 92. Contacts 94 are preferably formed on both sides of p-i-n photodiode 90 which provide electrical access to the anode of p-i-n photodiode 90 as well as to the anode of the VCSEL 91 which underlies p-i-n photodiode 90. Finally, contact 96 is formed on n-type layer 104 to form the cathode of p-i-n photodiode 90. An anti-reflection coating preferably having a thickness of about one quarter wavelength is applied to photo-receiving surface 101.

A simplified schematic of the structure of Figure 5a is shown in Figure 5b. VCSEL 92 is operated with forward bias between anode terminal 82 and cathode terminal 98 to produce radiation 84 having a wavelength of λ . p-i-n photodiode 90 is operated with reverse bias between cathode contact 96 and anode contacts 94. Moreover, anode contacts 94 are shorted to substrate contact 98 to ensure that VCSEL 91 will not become forward biased and emit light. Thus, VCSEL 92 can be operated to emit light encoded with data to be transmitted to a remote receiver employing a similar structure, and p-i-n photodiode 90 can operate to receive radiation 86 which is encoded with data received from the same remote terminal.

Those of skill in the art will recognize that the exact order in which the process steps take place, as well as the particular material system used, are irrelevant to the patentability of the present invention. For example, one material system might include a GaAs substrate, GaAs quantum wells, DBR layers of AIAs and AlGaAs, and an intrinsic layer of GaAs. The p and n layers of the p-i-n would also be made of AlGaAs. Other known material systems may be used to produce different wavelengths of emitted radiation and the particular dimensions of the integrated devices may be changed to suit particular transmission modes or packaging requirements. Moreover, although it is

desirable that the photolithographically defined spacings between the transmit and receive pairs are preferably small, of course larger spacings can be easily accomodated by the present invention.

Those of skill in the art will recognize many advantages of the second preferred embodiment of Figure 5a is that a typical process used to create arrays of VCSELs, including the isolation implant commonly used to separate the individual VCSELs of the array, can be used to create arrays of VCSEL/p-i-n photodiode pairs. The additional steps required to build the p-i-n photodiode on top of the VCSEL process are negligible in cost. Moreover, the difference in the thickness of the two devices is also negligible for purposes of facilitating near-field coupling of the devices to fibers to eliminate the need for optics. Additionally, due to the underlying second mirror of inoperable VCSEL 91, any light not absorbed by the intrinsic layer 102 of p-i-n photodiode 90 will be reflected back into intrinsic layer 102, thus having a second chance to be absorbed. Finally, the thicker the intrinsic layer, the lower the capacitance of the p-i-n diode (the faster its operation) and the better its optical efficiency.

Figure 6a illustrates how the commonly used single fiber round ferrule can be implemented using two or more fibers. Such fibers are now currently available from Siecor as prototypes. The cylindrical ferrule 110 has the same dimensions (i.e., 2.5 mm) as those ferrules commonly used with only one fiber. Thus, one fiber 112 can be used for transmitting data as coupled to a VCSEL while fiber 114 can be used to receive data from a remote transmitter as coupled to a photodetector.

Figure 6b illustrates a commonly available rectangular ferrule which can have eight or more fibers 122, and which has guides 120 for receiving alignment pins. Rectangular ferrule 116 typically has a polished face 118 for coupling to an array of transmitting VCSELs. This rectangular ferrule 116 can be easily adapted to devices made in accordance with the present invention, such that each pair of fibers 122 can be aligned with a pair of integrated VCSEL/photodetectors.

Figure 7a illustrates how a single VCSEL/photodetector pair could be packaged using standard lead-frame technology to be interfaced to a rectangular multifiber ferrule such as the one illustrated in Fig. 6b. Integrated transmit/receive chip 130 can be epoxied to lead frame 128 and then bonded to bond pads 141 via bond wires 143. If optics are required, lenses 138 and 136 can be formed over VCSEL 89, 92 and photodetector 62,90 respectively, either using materials which are formed over chip 130 during the manufacturing of chip 130 or such optics can be integrated within the surface of the plastic encapsulation formed by the package. Lead frame 128 can also have guide pins 140 to be used in conjunction with a rectangular ferrule such as the one shown in Figure 6b. Figure 7b shows a side view of Figure 7a to illustrate the use of optics over photodetector 62, 90 and VCSEL 89, 92.

Figure 7c illustrates how lead frame 128 can be butt coupled to a rectangular ferrule 150 containing two fibers 124 and 126. If distance 160 is fairly precisely known, and distance 147 between fibers 124 and 126 is fairly precise, a fairly accurate alignment can be achieved between fibers 124 and 126 and VCSEL 89, 92 and photodetector 62, 90, because the distance between VCSEL 89, 92 and photodetector 62, 90 are fairly precise based on the photo-optical alignment process used in manufacturing the integrated semiconductor 130. Thus, a fairly accurate positioning of the chip 130 with respect to the lead frame 128 during packaging will provide a reasonably accurate passive alignment. Of course, fine alignment can be achieved using well-known active alignment techniques. A further advantage of the coupling technique shown in Figure 8 is that no optics must be interposed between package 146 and ferrule 150 if the coupling distance 152 is close enough. Of course, a flat transmissive surface 148 can be easily achieved on package 146.

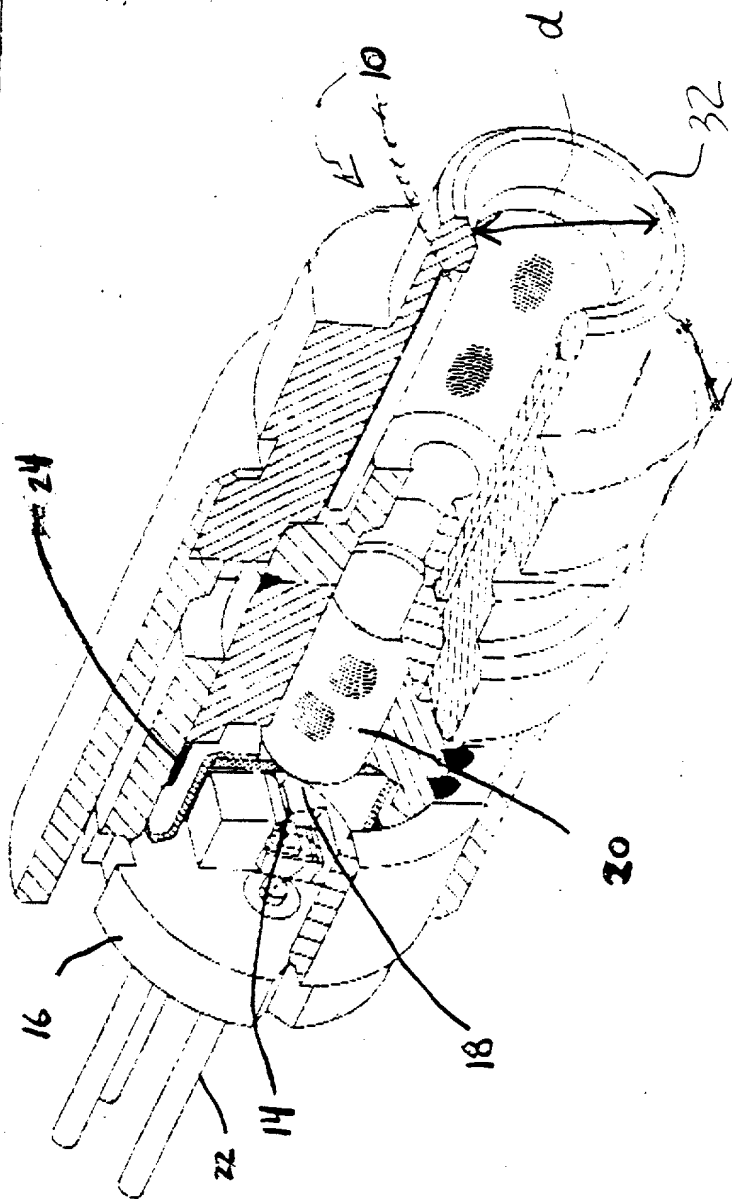
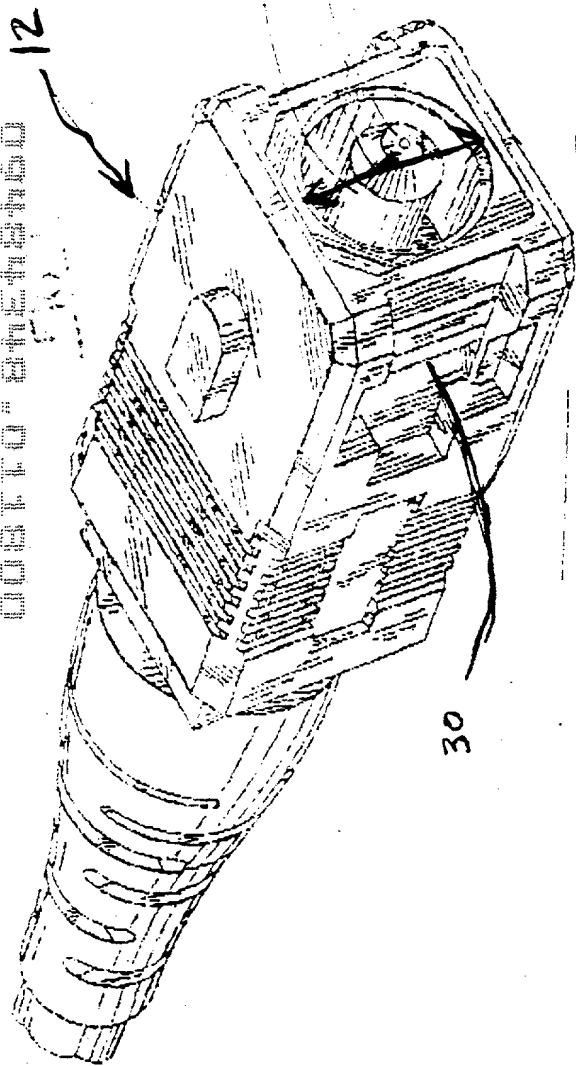
Fig. 8 illustrates a lead-frame package which can be used to interface with a round multifiber ferrule such as the two-fiber ferrule of Fig. 6a. Barrel 127 is designed to precisely mate with the round ferrule of Fig. 6b.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	2101	2102	2103	2104	2105	2106	2107	2108	2109	2110	2111	2112	2113	2114	2115	2116	2117	2118	2119	2120	2121	2122	2123	2124	2125	2126	2127	2128	2129	2130	2131	2132	2133	2134	2135	2136	2137	2138	2139	2140	2141	2142	2143	2144	2145	2146	2147	2148	2149	2150	2151	2152	2153	2154	2155	2156	2157	2158	2159	2160	2161	2162	2163	2164	2165	2166	2167	2168	2169	2170	2171	2172	2173	2174	2175	2176	2177	2178	2179	2180	2181	2182	2183	2184	2185	2186	2187	2188	2189	2190	2191	2192	2193	2194	2195	2196	2197	2198	2199	2200	2201	2202	2203	2204	2205	2206	2207	2208	2209	2210	2211	2212	2213	2214	2215	2216	2217	2218	2219	2220	2221	2222	2223	2224	2225	2226	2227	2228	2229	2230	2231	2232	2233	2234	2235	2236	2237	2238	2239	2240	2241	2242	2243	2244	2245	2246	2247	2248	2249	2250	2251	2252	2253	2254	2255	2256	2257	2258	2259	2260	2261	2262	2263	2264	2265	2266	2267	2268	2269	2270	2271	2272	2273	2274	2275	2276	2277	2278	2279	2280	2281	2282	2283	2284	2285	2286	2287	2288	2289	2290	2291	2292	2293	2294	2295	2296	2297	2298	2299	2300	2301	2302	2303	2304	2305	2306	2307	2308	2309	2310	2311	2312	2313	2314	2315	2316	2317	2318	2319	2320	2321	2322	2323	2324	2325	2326	2327	2328	2329	2330	2331	2332	2333	2334	2335	2336	2337	2338	2339	2340	2341	2342	2343	2344	2345	2346	2347	2348	2349	2350	2351	2352	2353	2354	2355	2356	2357	2358	2359	2360	2361	2362	2363	2364	2365	2366	2367	2368	2369	2370	2371	2372	2373	2374	2375	2376	2377	2378	2379	2380	2381	2382	2383	2384	2385	2386	2387	2388	2389	2390	2391	2392	2393	2394	2395	2396	2397	2398	2399	2400	2401	2402	2403	2404	2405	2406	2407	2408	2409	2410	2411	2412	2413	2414	2415	2416	2417	2418	2419	2420	2421	2422	2423	2424	2425	2426	2427	2428	2429	2430	2431	2432	2
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- 5

ABSTRACT

A monolithically integrated VCSEL and photodetector, and a method of manufacturing same, are disclosed for applications where the VCSEL and photodetector require separate operation such as duplex serial data communications applications. A first embodiment integrates a VCSEL with an MSM photodetector on a semi-insulating substrate. A second embodiment builds the layers of a p-i-n photodiode on top of layers forming a VCSEL using a standard VCSEL process. The p-i-n layers are etched away in areas where VCSELs are to be formed and left where the photodetectors are to be formed. The VCSELs underlying the photodetectors are inoperable, and serve to recirculate photons back into the photodetector not initially absorbed. The transmit and receive pairs are packaged in a single package for interface to multifiber ferrules. The distance between the devices is precisely defined photolithographically, thereby making alignment easier.



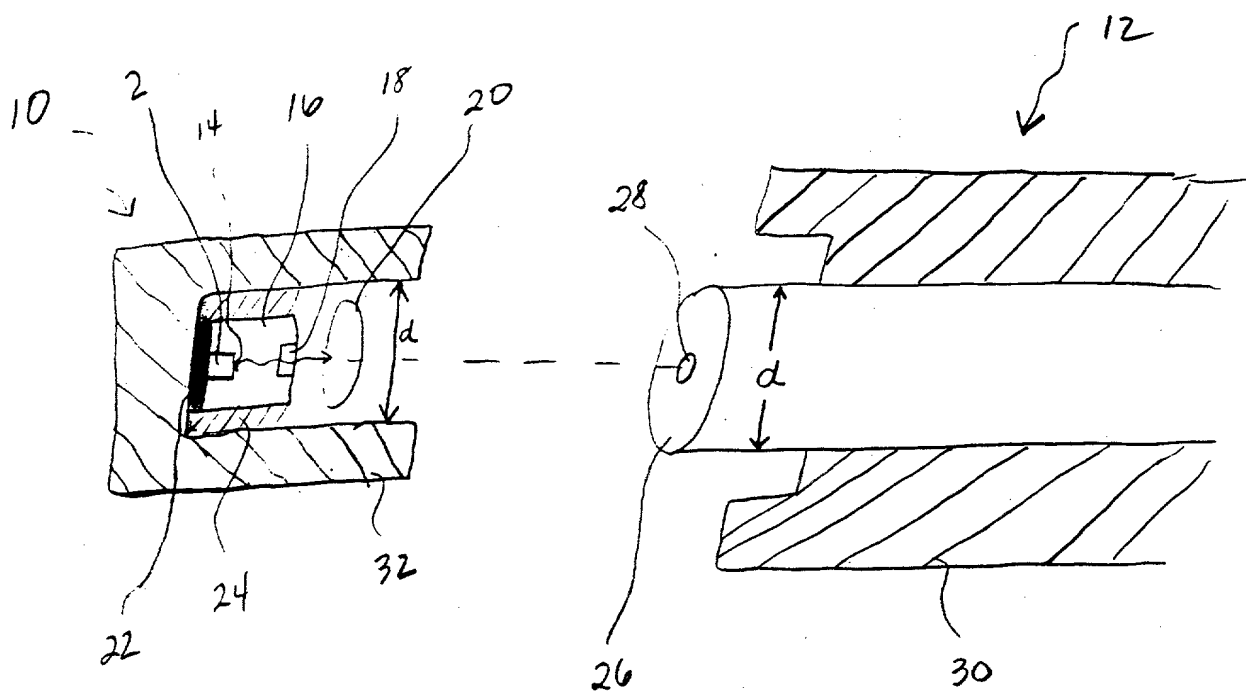


Fig. 1c (Prior Art)

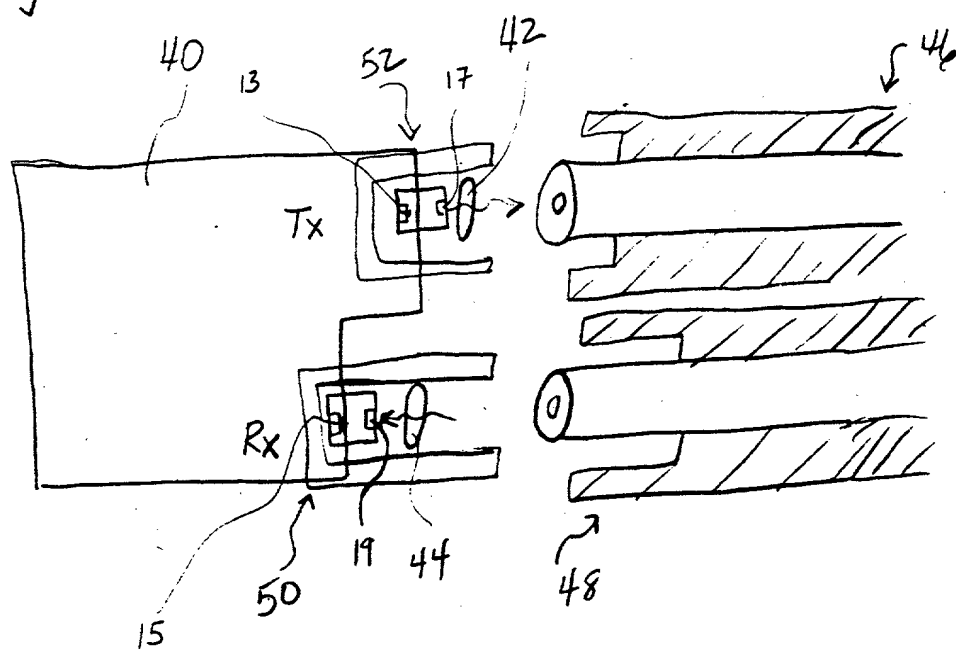


Fig. 1d (Prior Art)

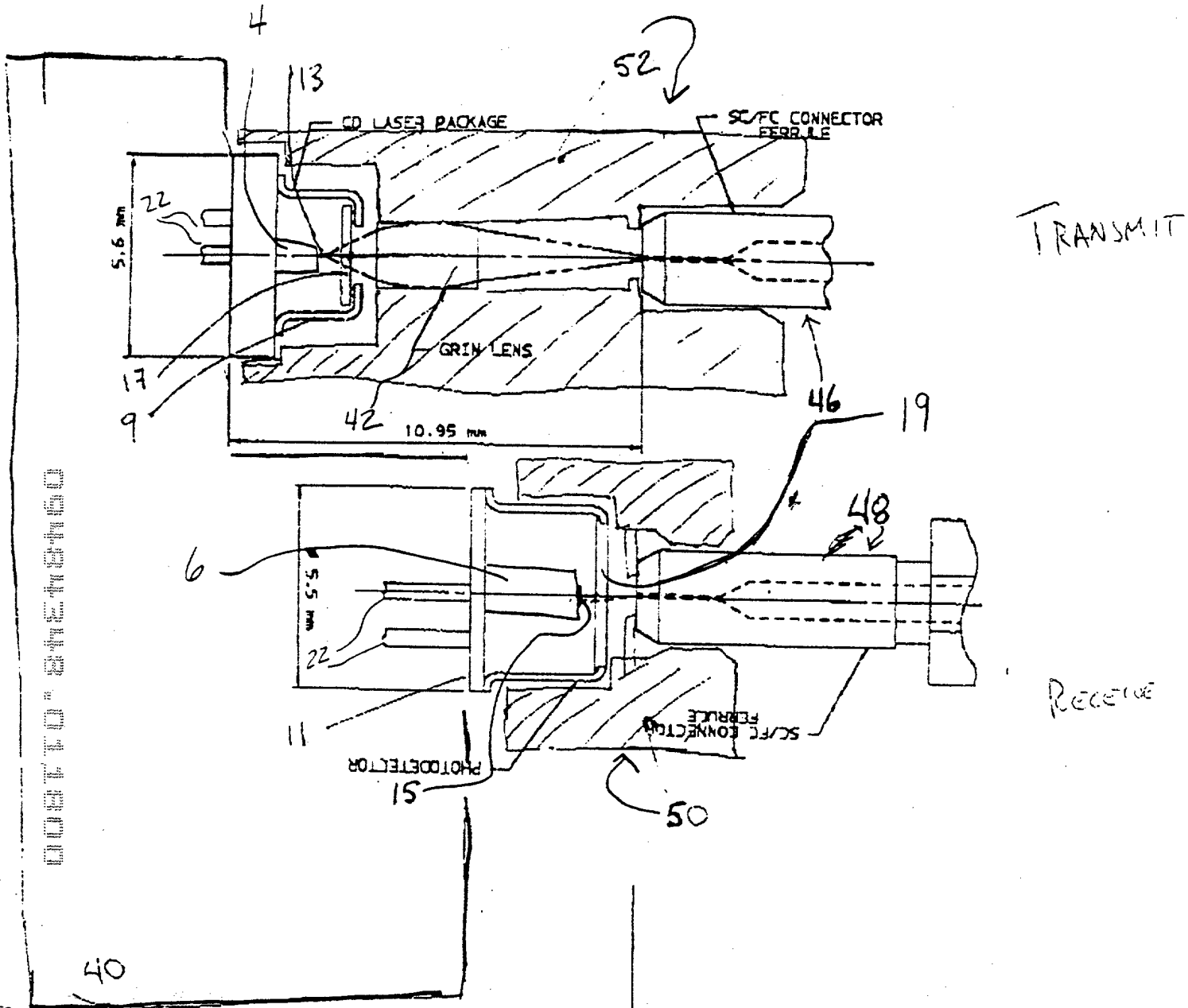


Fig 2

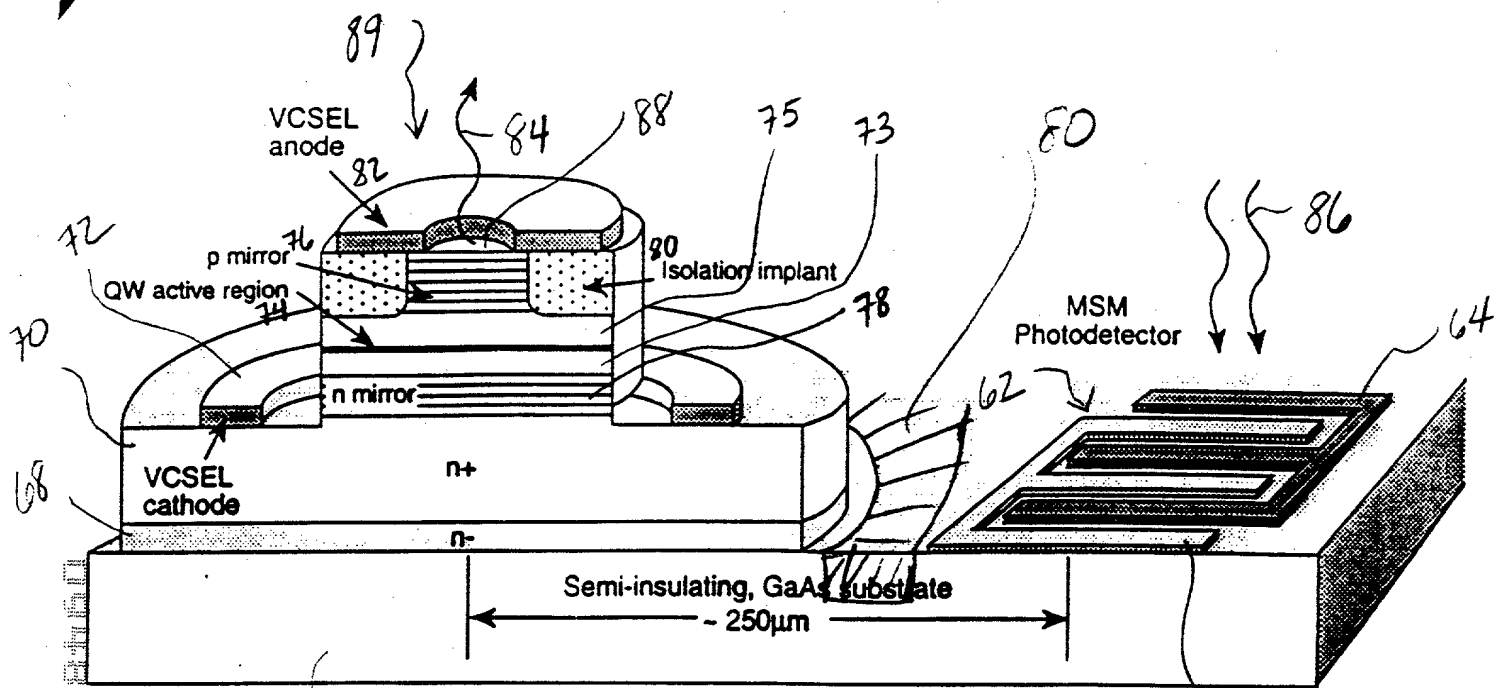


Figure 3 Device Cross Section

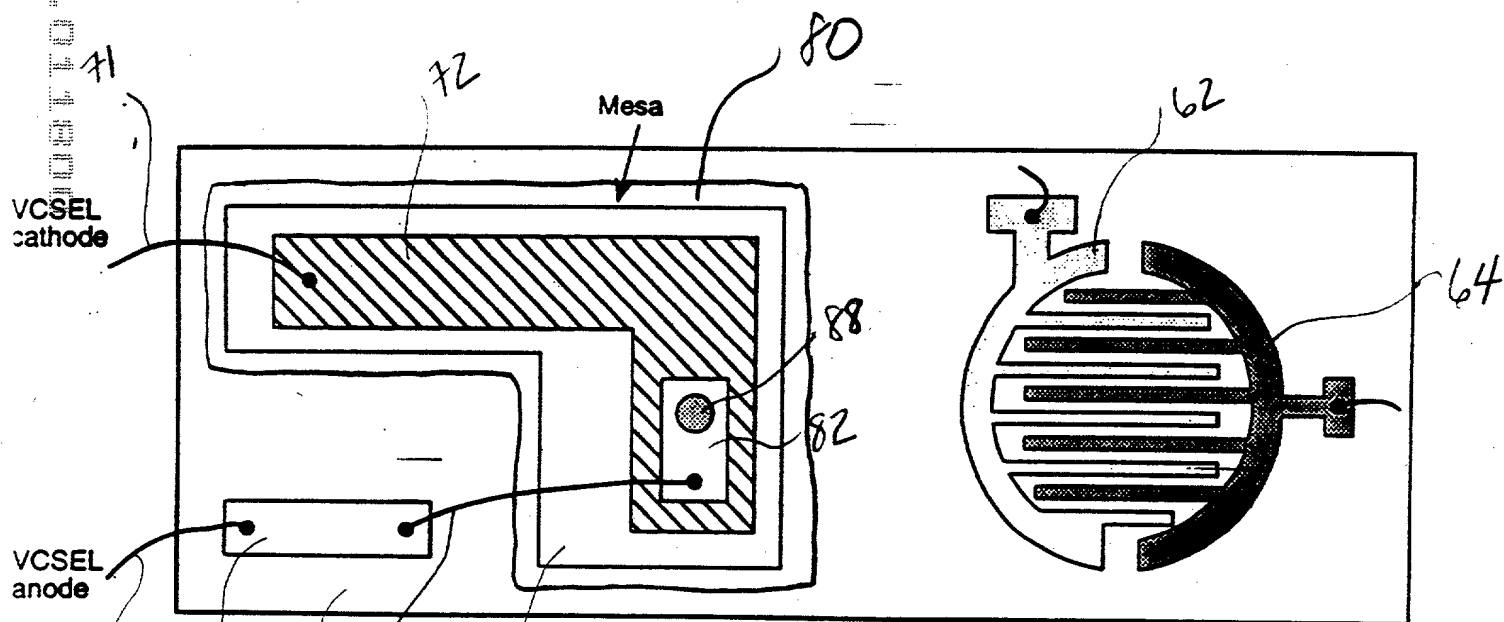


Figure 4 Monolithic Plan View

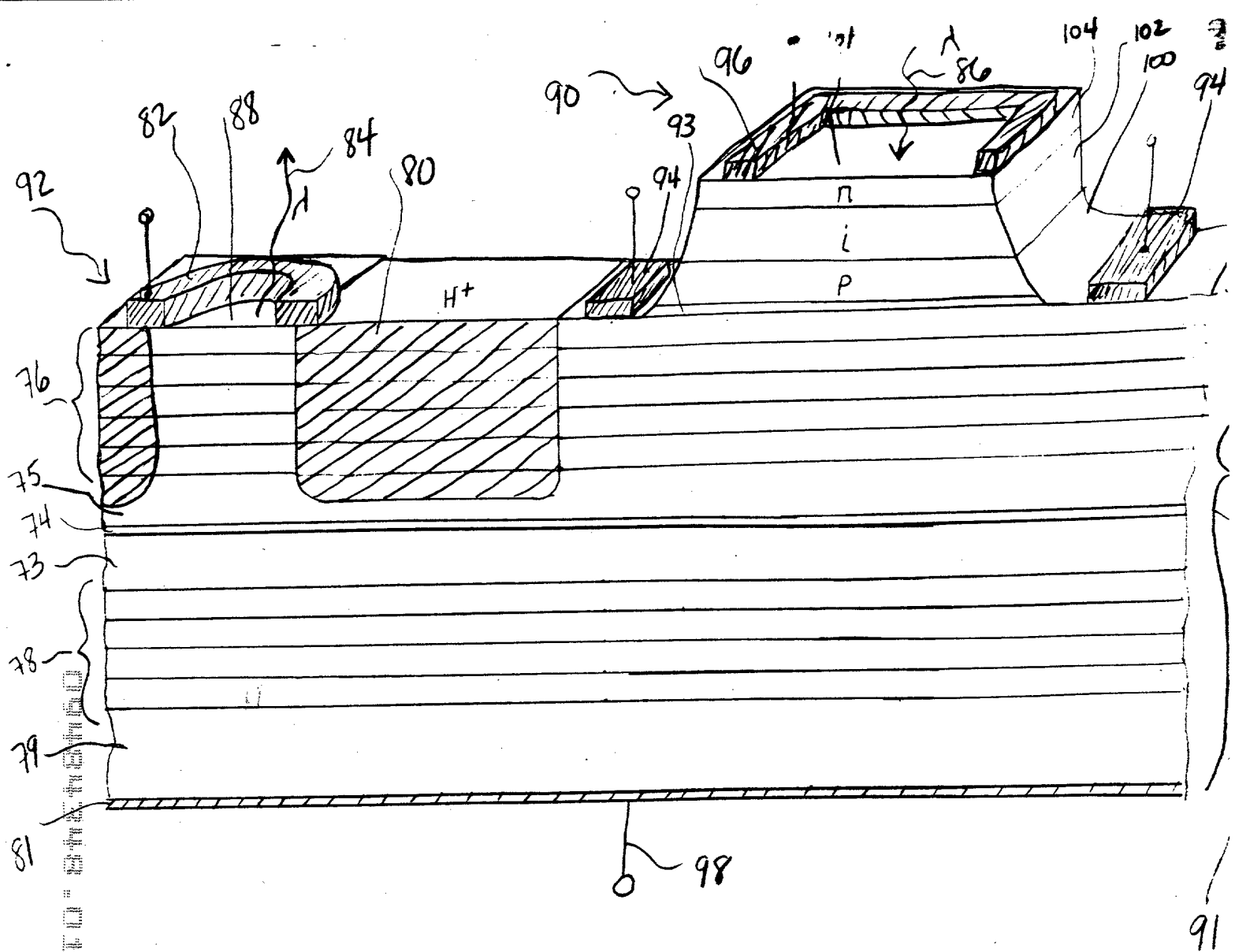


Fig. 5a

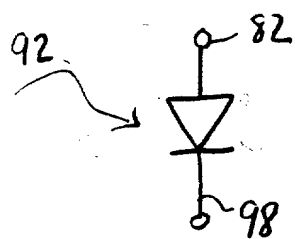
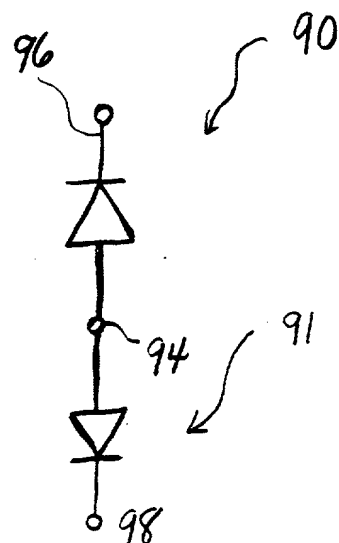


Fig. 5b



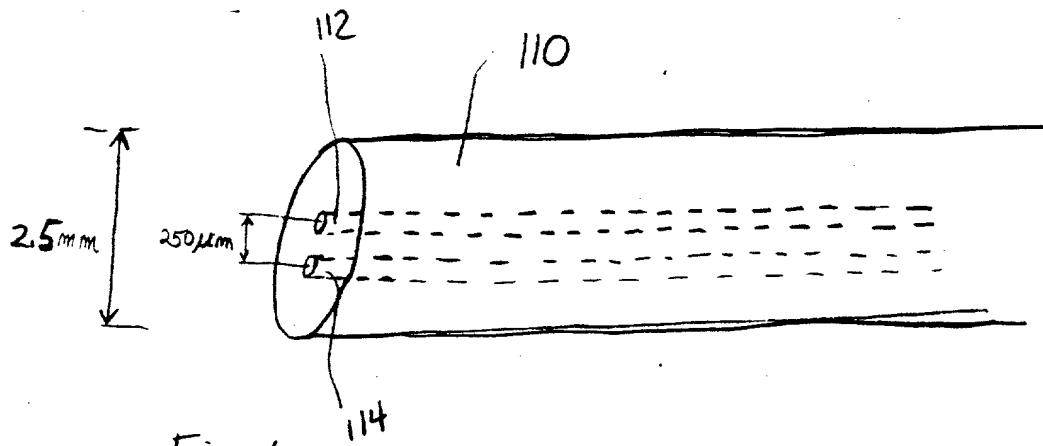


Fig. 6a

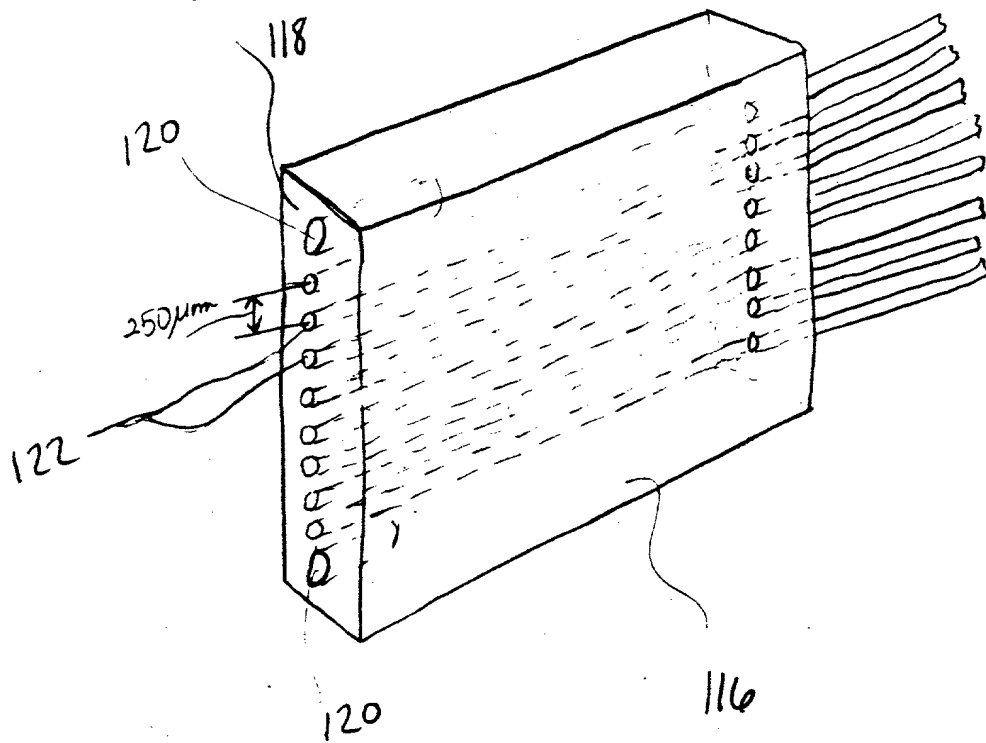
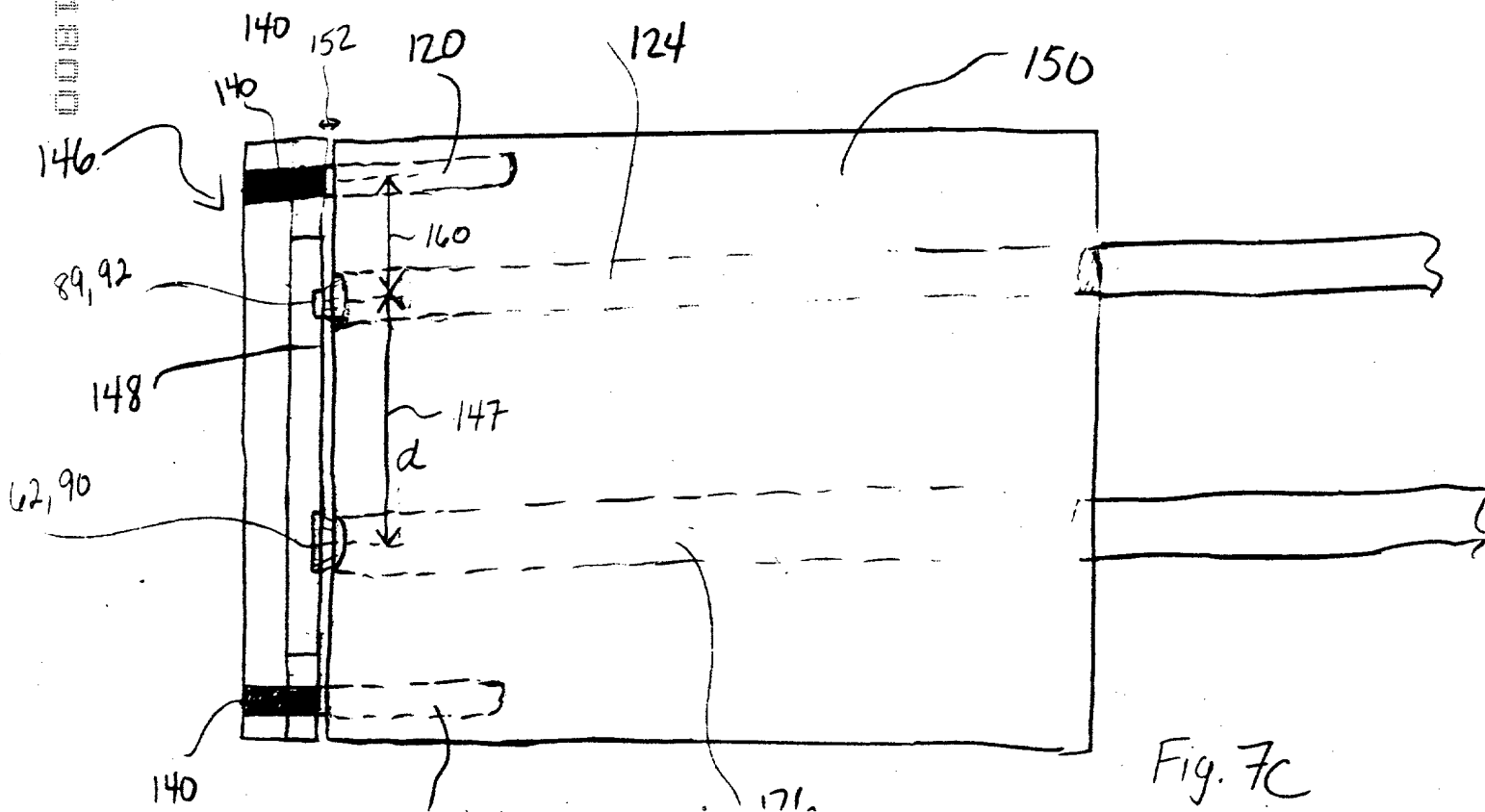
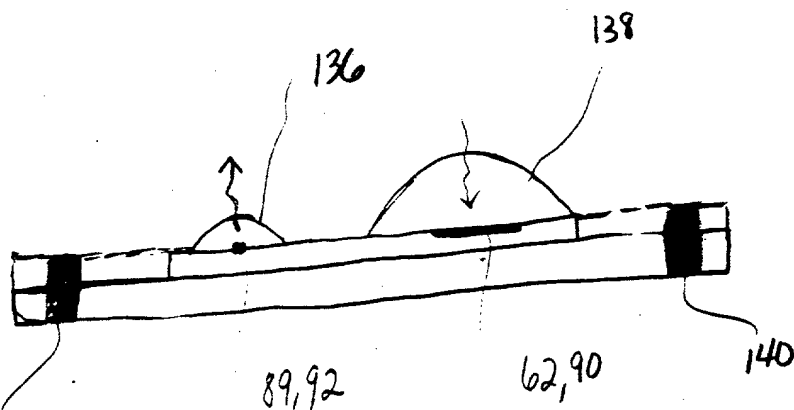
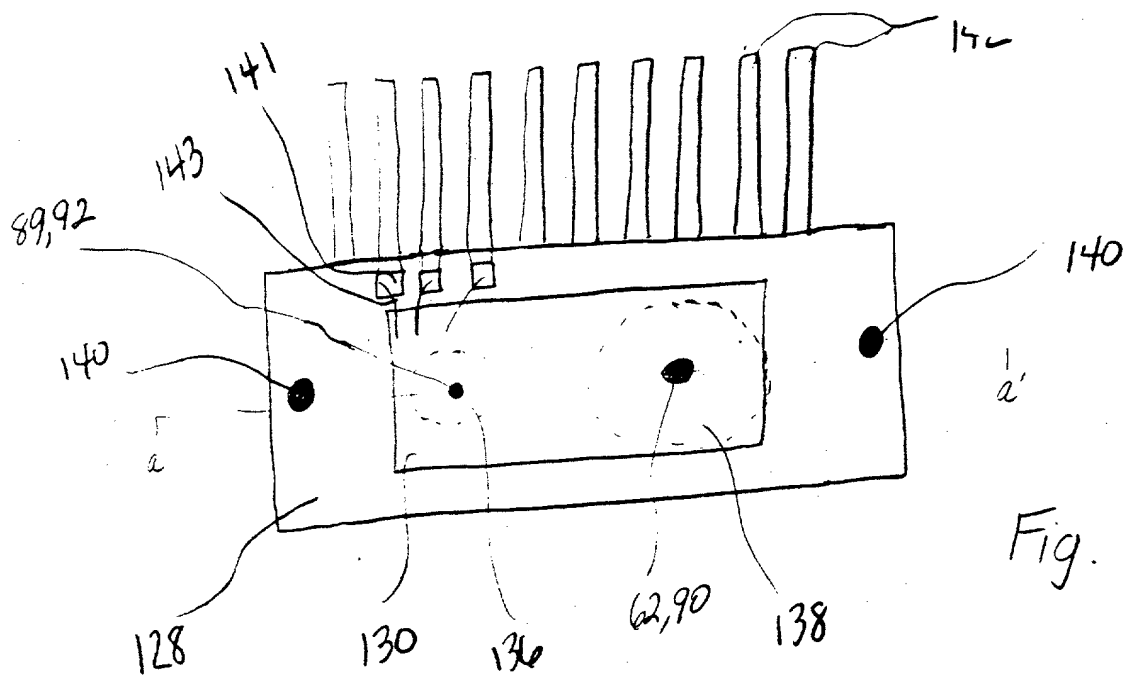
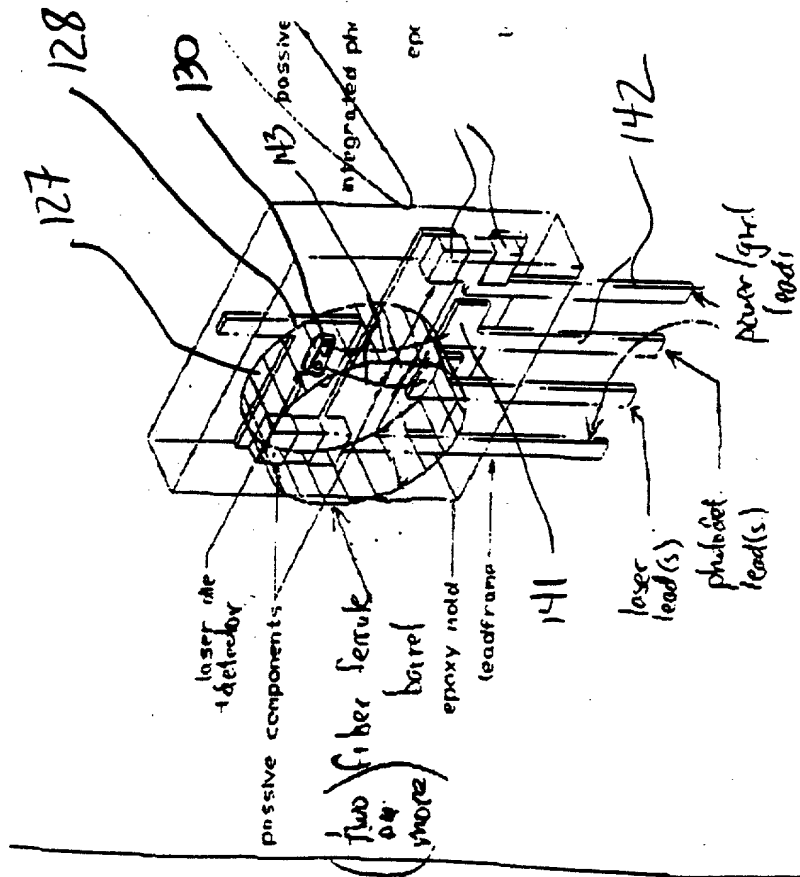


Fig. 6b





Description	
Proposed design for encapsulated leadframe transmit/receive device	
Drawn By: S. White	
Dimensions in inches (mm)	

F. R.

RULE 63 (37 C.F.R. 1.63)
DECLARATION AND POWER OF ATTORNEY
FOR PATENT APPLICATION
IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

As a below named inventor, I hereby declare that my residence, post office address and citizenship are as stated below next to my name, and I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled A CLOSELY-SPACED VCSEL AND PHOTODETECTOR FOR APPLICATIONS REQUIRING THEIR INDEPENDENT OPERATION, the specification of which (CHECK applicable BOX(ES)).

___ is attached hereto.

X was filed on February 1, 1996 as U.S. application Serial No. 08/593,117

___ was filed as PCT international application No. PCT/___/___ on ___ and (if applicable to U.S. or PCT application) was amended on ___.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the examination of this application in accordance with 37 C.F.R. 1.56(a) and 35 U.S.C. 102. I hereby claim foreign priority benefits under 35 U.S.C. 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date (1) before that of the application on which priority is claimed, or (2) if no priority claimed, before the filing date of this application:

PRIOR FOREIGN APPLICATION(S)

PRIORITY CLAIMED

Number Country Day/MONTH/Year Filed

YES NO

I hereby claim the benefit under 35 U.S.C. 120/365 of all United States and PCT international applications listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in such prior applications in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose material information as defined in 37 C.F.R. 1.56(a) which occurred between the filing date of the prior applications and the national or PCT international filing date of this application:

PRIOR U.S. OR PCT APPLICATION(S)

Status: patented,

Application Serial No.

Day/MONTH/Year

pending, abandoned

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so make are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

And I hereby appoint IRELL & MANELLA LLP, 1800 Avenue of the Stars, Suite 900, Los Angeles, California 90067, telephone number (310) 277-1010 (to whom all communications are to be directed) and Robert Steinberg, Registration No. 33,144; Bruce D. Kuyper, Registration No. 33,937; Gary Frischling, Registration No. 35,515; Robert Strawbrich, Registration No. 36,692; and Jeffrey L. Blatt, Registration No. 30,244 (all of the same address) individually and collectively my attorneys to transact all business in the Patent and Trademark Office connected therewith and with the resulting patent.

1) INVENTOR'S SIGNATURE Stanley E. Swirhun Date 4/15/96
Inventor's Name (typed) Stanley E. Swirhun Canada
First MI Family Name Citizenship

Residence 1471 Cassin Court, Boulder, Colorado 80303 (State/Foreign Country)
Post Office Address (Include Zip Code) 1471 Cassin Court, Boulder, Colorado 80303 U.S.A.

2) INVENTOR'S SIGNATURE Jeffrey W. Scott Date 4/15/96
Inventor's Name (typed) Jeffrey W. Scott United States
First MI Family Name Citizenship

Residence 3455 Table Mesa Drive, Apt. 236L, Boulder, Colorado 80303 (State/Foreign Country)
Post Office Address (Include Zip Code) 3455 Table Mesa Drive, Apt. 236L, Boulder, Colorado 80303 U.S.A.

3) INVENTOR'S SIGNATURE _____ Date _____
Inventor's Name (typed) _____
First MI Family Name Citizenship

Residence _____ (State/Foreign Country)
Post Office Address (Include Zip Code) _____

4) INVENTOR'S SIGNATURE _____ Date _____
Inventor's Name (typed) _____
First MI Family Name Citizenship

Residence _____ (State/Foreign Country)
Post Office Address (Include Zip Code) _____

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Vixel Corporation
 Application No. : 08/803,891
 Filed : February 21, 1997
 Title : CLOSELY SPACED VCSEL AND PHOTODETECTOR FOR
 APPLICATIONS REQUIRING THEIR INDEPENDENT OPERATION

Grp./Div. : 2812
 Examiner : L. Pham

Docket No. : 33723/DBP/C715

SUBSTITUTION OF ATTORNEY BY ASSIGNEE

Commissioner of Patents and Trademarks
 Washington, D.C. 20231

Commissioner:

Cielo Communications, Inc., assignee of the entire interest in and to the above-identified U.S. patent application under an Assignment that was sent for recordal in the U.S. Patent and Trademark Office on January 18, 1999 under separate cover (copy attached herewith), hereby revokes all previous Powers of Attorney and appoints:

R. W. Johnston	(17,968)	Vincent G. Gioia	(19,959)	Robert D. Rowlett	(41,279)
D. Bruce Prout	(20,958)	Edward R. Schwartz	(31,135)	Kathleen M. Olster	(42,052)
Hayden A. Carney	(22,653)	John D. Carpenter	(34,133)	Daniel M. Cavanagh	(41,661)
Richard J. Ward, Jr.	(24,187)	David A. Plumley	(37,208)	Molly A. Holman	(40,022)
Russell R. Palmer, Jr.	(22,994)	Wesley W. Monroe	(39,778)	Lucinda G. Auciello	(42,270)
LeRoy T. Rahn	(20,356)	Grant T. Langton	(39,739)	Norman E. Carte	(30,455)
Richard D. Seibel	(22,134)	Constantine Marantidis	(39,759)	Joel A. Kauth	(41,886)
Walter G. Maxwell	(25,355)	John W. Eldredge	(37,613)	Patrick Y. Ikehara	(42,681)
William P. Christie	(29,371)	Gregory S. Lampert	(35,581)	Mark Garscia	(31,953)
David A. Dillard	(30,831)	Craig A. Gelfound	(41,032)	Gary J. Nelson	(P-44,257)
Thomas J. Daly	(32,213)	Syed A. Hasan	(41,057)	Raymond R. Tabandeh	(P-43,945)

all members or associates of or of counsel to the firm CHRISTIE, PARKER & HALE, LLP, telephone (626) 795-9900, as principal attorneys with power to appoint associate attorneys, to prosecute this application and any subsequent application based on the disclosure of this application, and to transact all business in the Patent and Trademark Office connected with this application and any subsequent application.

Application No. 08/803,891

The authority under this Power of Attorney of each person named above shall automatically terminate and be revoked upon such person ceasing to be a member or associate of or of counsel to that law firm.

Please address all correspondence to CHRISTIE, PARKER & HALE, LLP, P.O. Box 7068, Pasadena, California 91109-7068.

Cielo Communications, Inc.

Date 11/12/99

By Mark A. Harrington

Name: Mark A. Harrington

Title: CFO

DBP/crb

TMW PAS165867.1-*12/31/98 8:27 am